(1)

AD-A230 480

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	December 1990	Professional paper

4. TITLE AND SUBTITLE
IRRADIATION OF LWIR DETECTORS WITH X-RAYS GENERATED NEAR THE SAMPLE

5. FUNDING NUMBERS
PR: XA02
WU: DN112 077
PE: 0603220C

6. AUTHOR(S)
L. D. Flesner, M. E. O'Brien and C. G. Rogers

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Ocean Systems Center
San Diego, CA 92152-5000

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army
Strategic Defense Command
Huntsville, AL 35807-3801

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

A novel approach for testing the effects of ionizing radiation on long-wavelength infrared (LWIR) detectors operating in a thermally-shielded environment is described. An electron beam is introduced into a cryogenic chamber and used to generate a low-energy X-rays in a cold target foil proximate to the detector. Applications of the method include ionization induced noise and accumulated dose studies.

Published: *IEEE* Transactions on Nuclear Science, December 1989.

14. SUBJECT TERMS
electro-optics
sensors
radiometry
devices
infrared
detectors

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	SAME AS REPORT

IRRADIATION OF LWIR DETECTORS WITH X-RAYS GENERATED NEAR THE SAMPLE[1]

L. D. Flesner and M. E. O'Brien
Naval Ocean Systems Center, Code 56
San Diego, California, 92152-5000
(619) 553-1044

C. G. Rogers and T. G. Moore
Aerojet Electrosystems
P.O. Box 296
Azusa, California 91702

ABSTRACT

A novel approach for testing the effects of ionizing radiation on long-wavelength infrared (LWIR) detectors operating in a thermally-shielded environment is described. An electron beam is introduced into a cryogenic chamber and used to generate low-energy X-rays in a cold target foil proximate to the detector. Applications of the method include ionization induced noise and accumulated dose studies.

INTRODUCTION

A need exists for LWIR detectors capable of operating effectively in an ionizing radiation environment. The sensitivity of LWIR detectors to ionizing radiation includes effects associated with single pulses, persistent dose rate (gamma noise), and accumulated dose degradation.

To operate and test such detectors they must be contained in apparatus which provides for cooling the detector and shielding it from room temperature thermal radiation. Introducing ionizing radiation into cryogenic apparatus poses additional problems which have been addressed in a variety of ways. Persistent dose rate testing is generally accomplished by exposing the detectors to Co-60 gamma radiation. Total dose testing is also sometimes done using gamma sources. Some difficulties associated with gamma sources are safety hazard, inability to rapidly modulate the exposure for comparison of clear versus gamma-irradiated performance, and heating effects at higher dose rates. The maximum dose rate available with gamma sources is about 100 rad(Si)/sec. The localized irradiation technique described below has the capability of achieving much higher dose rates, as well as demonstrating other advantages.

In this paper we describe an economical and relatively non-hazardous approach which has been applied for persistent ionization-induced noise testing in Si:As impurity band conduction (IBC) detectors, and which is also readily applicable for total dose testing. In addition, the ionizing radiation source can be pulsed or modulated in order to synchronize ionizing effects with the detector measurement procedure. This facilitates separation of the ionization effects from system noise or other phenomena which might confound the experiment. The ability to do pulse testing was a principal motivation for developing the technique, and an example of how the pulse testing capability has been exploited will be presented.

APPARATUS

The apparatus, which is illustrated in Figures 1 and 2, is a modification of equipment which has been used for direct electron excitation experiments in LWIR detectors. [1, 2, 3] A scanning electron microscope (SEM) has been conjoined with a cryogenic chamber in a manner permitting selective propagation of a focused electron beam onto a detector through an aperture in the thermal shield. The configuration allows the beam to scan across the sample, and a beam blanker installed in the SEM column enables measurement of the time dependence as well as the spatial dependence of the detector response.

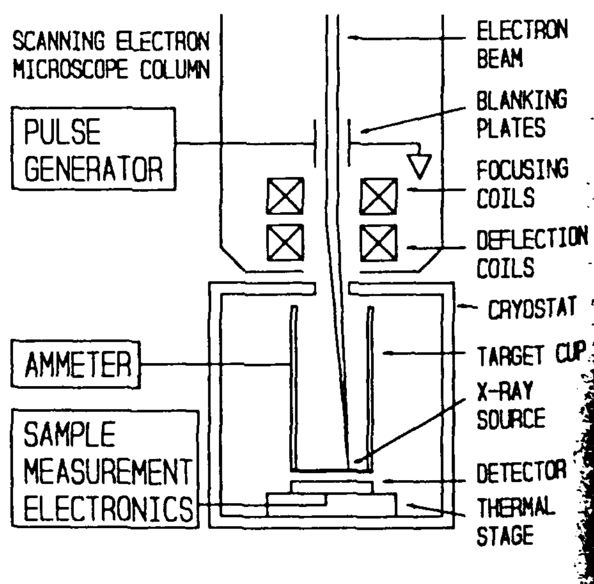

Figure 1. Schematic Representation of Apparatus.

91 1 9 045

[1] Supported by the U.S. Army Strategic Defense Command

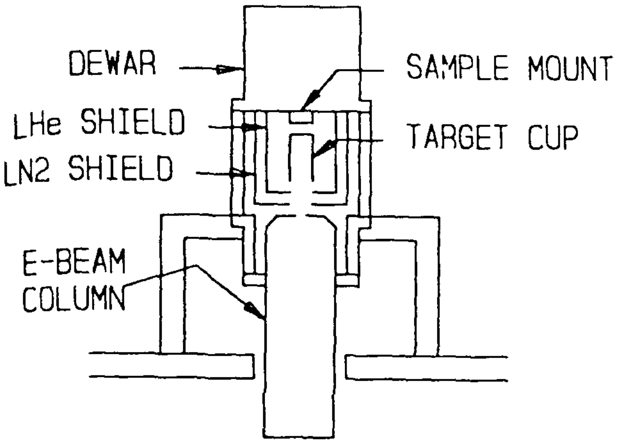

Figure 2. Apparatus configuration. The SEM column is inverted to simplify dewar design.

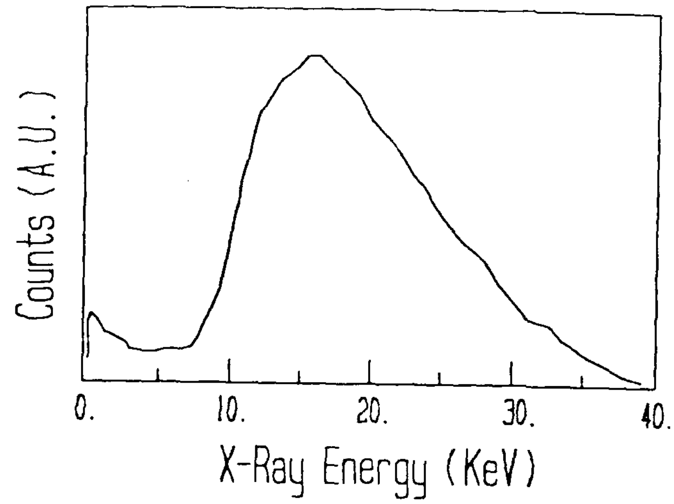

Figure 3. Energy dispersive X-ray spectrum of X-rays generated by aluminum target, and propagated through 100 μm of Al foil and 250 μm of Si prior to detection.

The principal limitation in using direct electron excitation is that at the 39 keV beam energy available, the penetration depth is only a few microns into the sample, and the active volume of the detector must be accessible to the beam. In order to alleviate this limitation the apparatus configuration was modified by introducing an aluminum target foil proximate to the sample as illustrated. Low-energy X-rays are generated in the foil by bremsstrahlung, and the X-rays readily penetrate through the foil and detector material. The target foil is situated at the bottom of a target cup. The target cup absorbs the incident electron current, which is measured for correlation with dosimetry. The cup also intercepts and absorbs thermal radiation entering the chamber through the aperture. The target foil is in thermal contact with the cryostat in order to avoid heating and consequent generation of thermal photons.

EXPERIMENTAL RESULTS

In order to observe the approximate spectrum of X-rays expected to reach a detector situated on the back of a silicon wafer, an experiment was conducted using a standard SEM. An aluminum target was irradiated by 39 keV electrons and the X-ray spectrum after propagation through 100 microns of Al foil and 250 microns of Si was measured using an EDAX model 9100 energy dispersive X-ray analysis system. The standard system geometry was used, with the detector situated above the target at an angle of 62 degrees relative the incident electron beam. A solid aluminum target was used, and a silicon wafer and layer of aluminum foil were interposed between the target and the detector. The result is shown in Fig. 3. It can be seen to peak at about 16 keV, with a cutoff of 39 keV as expected. The attenuation length of 20 keV X-rays in Si is about 1 mm.

Figure 4 shows a comparison of the pulse height spectrum produced in a Si:As IBC detector by Co-60 gamma irradiation and by the X-ray source. The 80 microcurie Co-60 source is attached to a wand and lowered into the LHe dewar to get it as close to the sample as practicable. The resultant gamma flux through the detector is roughly 5×10^8 photons/cm^2-s. The X-ray target is within 5 mm of the detector, and the incident beam current is 80 nA at 39 keV. As can be seen, the event rates are comparable while the maximum pulse amplitude is greater for the gammas, as would be expected for the larger energy range of the gamma induced Compton electrons. This difference will be discussed further in a later section.

A series of experiments were performed to assess the performance of a detector under development by Aerojet Electrosystems of Azusa, California. The detector is referred to as an AMCIDERO, for Accumulation-Mode Charge-Injection-Device Extrinsic-Read-Only. The AMCIDERO is an LWIR IBC-based device operated so that the noise induced by ionizing radiation is substantially reduced below that of a conventially operated IBC detector. This is achieved by internally integrating the extrinsic charge induced by infrared photons while intrinsic charges induced by ionizing radiation for the most part either recombine within the detector or drift out undetected. Extrinsic charge generation refers to excitation of electrons from the impurity band while intrinsic charge generation refers to excitation of electrons from the conduction band. The AMCIDERO is a two layer structure with an IR sensitive IBC layer and an undoped "blocking" layer, as shown in Fig. 5. The structure is similar to that used in conventional IBC detectors, but certain details of device fabrication are different, and the device is operated in an unconventional manner. Referring to Fig. 5, the bias voltage Vb is not constant, as for a typical IBC detector. During the store period, Vb is negative and the device internally integrates extrinsic charge due to IR excitation. At the end of the store period Vb is briefly pulsed to a positive level, and

A-1|20

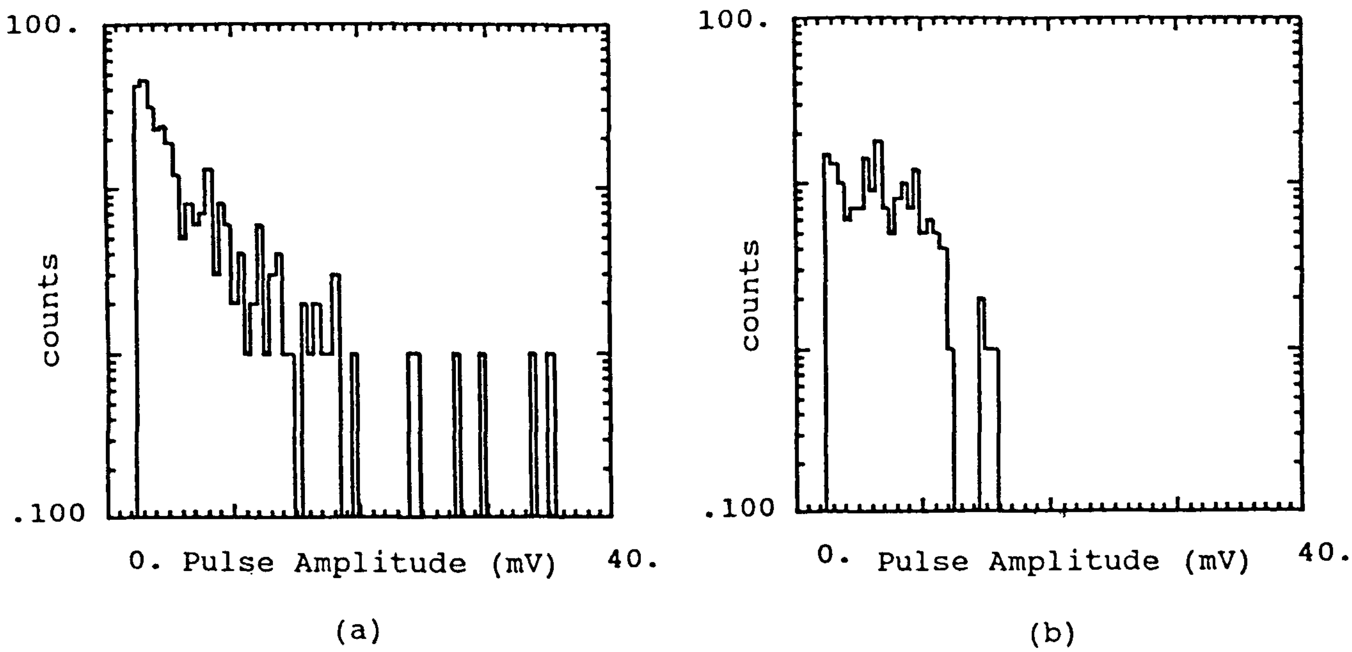

Figure 4. Pulse height distribution of noise spikes produced in a Si:As IBC detector by (a) Co-60 gamma radiation and (b) bremsstrahlung generated X-rays from a 39 keV electron beam.

charge accumulated in the device is transferred to an output circuit and measured. Ideally, in the absence of optical radiation, the read out charge would be zero. However, because of thermal generation and other effects, there is a "pedestal", or read out charge offset even in the absence of IR excitation. For the data below, the store period was 1 ms. The purpose of the experiments was to evaluate the extent to which X-rays incident during the store period affect the read out charge. This was done by confining the X-ray excitation to 100 microsecond pulse periods, which were then applied to the detector during various times during the store-readout cycle.

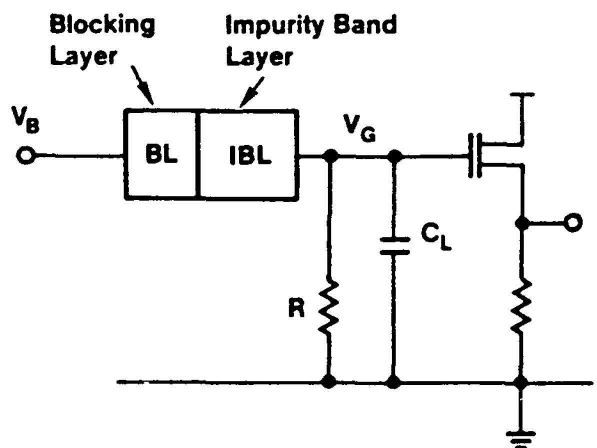

Figure 5. Schematic representation of the AMCIDERO detector and readout circuit.

Results are shown in Figs. 6 and 7. In these Figures, read out charge is measured many times, and the resulting histogram is plotted. In Fig. 6(a) the X-rays are off, and in 6(b) they are on continuously. The width of 6(a) is a result of fluctuations in the pedestal referred to above. In 6(b), data outside the normal fluctuation spectrum are observed, and these are due to the ionization events induced by the X-rays. These data were compared to data obtained using Co-60 gamma excitation, and the results were similar, except that the maximum deviations of the deviated data are larger for the gamma events. The dissimilarity was analogous to that illustrated for a conventional IBC detector in Fig. 4.

In Fig. 7(a) the 100 μs X-ray pulse is completed just prior to the read out pulse. In this case the data deviations are in the direction of reduced output from the average pedestal level. This is strikingly different from the behavior seen in Fig. 6(b), where data deviations in both directions are observed. In contrast, the effect of IR radiation is to cause a shift of the read out charge toward increased amplitude. In 7(b), the X-ray pulse is applied at the beginning of the store period, just subsequent to the read operation. In this case there are still deviated data, but the amplitude is much reduced, indicating that the effect of the intrinsic charge decays on a timescale short compared to the store period. In Fig. 7(c), the X-ray pulse is initiated just prior to the readout operation, so that it overlaps the read pulse and the beginning of the store period. From these data it is seen that the deviated data of increased amplitude are due to

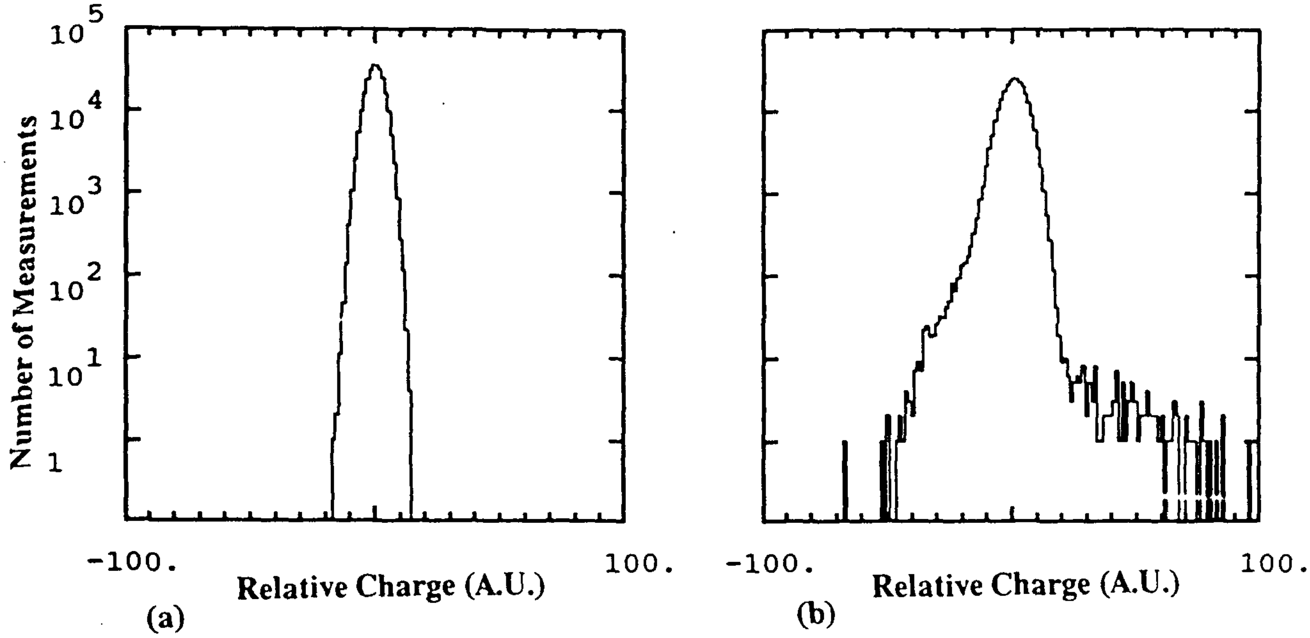

Figure 6. AMCIDERO charge readout histograms. In (a) there is X-ray excitation, and in (b) the X-ray source is continuously applied.

X-ray events occurring during the read interval, which is 15 μs.

DISCUSSION

Although a detailed analysis of the foregoing results is beyond the scope of the present paper, we note that the ability to probe with pulsed excitation has made it possible to determine that the AMCIDERO responds very differently to intrinsic ionization than to IR radiation, and further that intrinsic ionization occurring during the store period has a very different effect than does ionization during the brief read period. We were also able to quantitatively measure the decay time of the intrinsic ionization induced effect by moving the X-ray pulse to various times during the store period. It was found that this decay time was much shorter than the retention time for IR generated extrinsic charge. The significance of these results is that they provide insight into how the AMCIDERO discriminates between different excitation processes, and when these results are fully understood, it will be possible to improve the performance of similar detectors.

Because of the low energy of the X-rays relative to the gammas, the simulation fidelity of the technique for ionization noise generation is not exact. A conceptual comparison of the ionization effects of 39 keV electrons, low energy X-rays, and gamma induced Compton electrons is illustrated in Fig. 8. The 39 keV electrons produce a random walk excitation event with a penetration depth of about 10 μm in Si. The low energy X-ray scatters an electron with an energy comparable to the X-ray energy, which is on the order of 20 keV for the experiments described above. The range of a 20 keV electron is only about 3 μm in Si, and thus a single excitation event is very localized, although the events can occur throughout the volume of a silicon wafer. The maximum ionization charge which can be produced per event is also limited by the energy available. In contrast to the localized nature of the X-ray induced event, the energy of a gamma scattered electron is hundreds of keV, and the penetration distance is large compared to typical detector thicknesses. If the electron track is within and parallel to the active layer, then very large noise pulses can result infrequently, and these are seen experimentally.

The significance of the dissimilarities noted above is dependent upon the application. The simulation fidelity for accumulated dose phenomena has been extensively investigated for other technologies. [4] In the application described above, the differences in noise pulse spectra did not cause difficulty, since the issues under investigation did not require exact simulation. Additional experiments using higher energy electron sources are in progress to further explore the utility of low energy simulation for gamma noise problems.

The equipment used for the present work was originally designed for small electron beam spot size, which is not essential for the approach described. Alternative electron beam sources such as cathode ray tube guns could be easily employed, and other configurations for placing the X-ray target close to the sample are also conceivable. Employing an X-ray tube external to the cryogenic test chamber is also a possibility, but would require introducing the X-rays into the chamber through special windows. It would be difficult

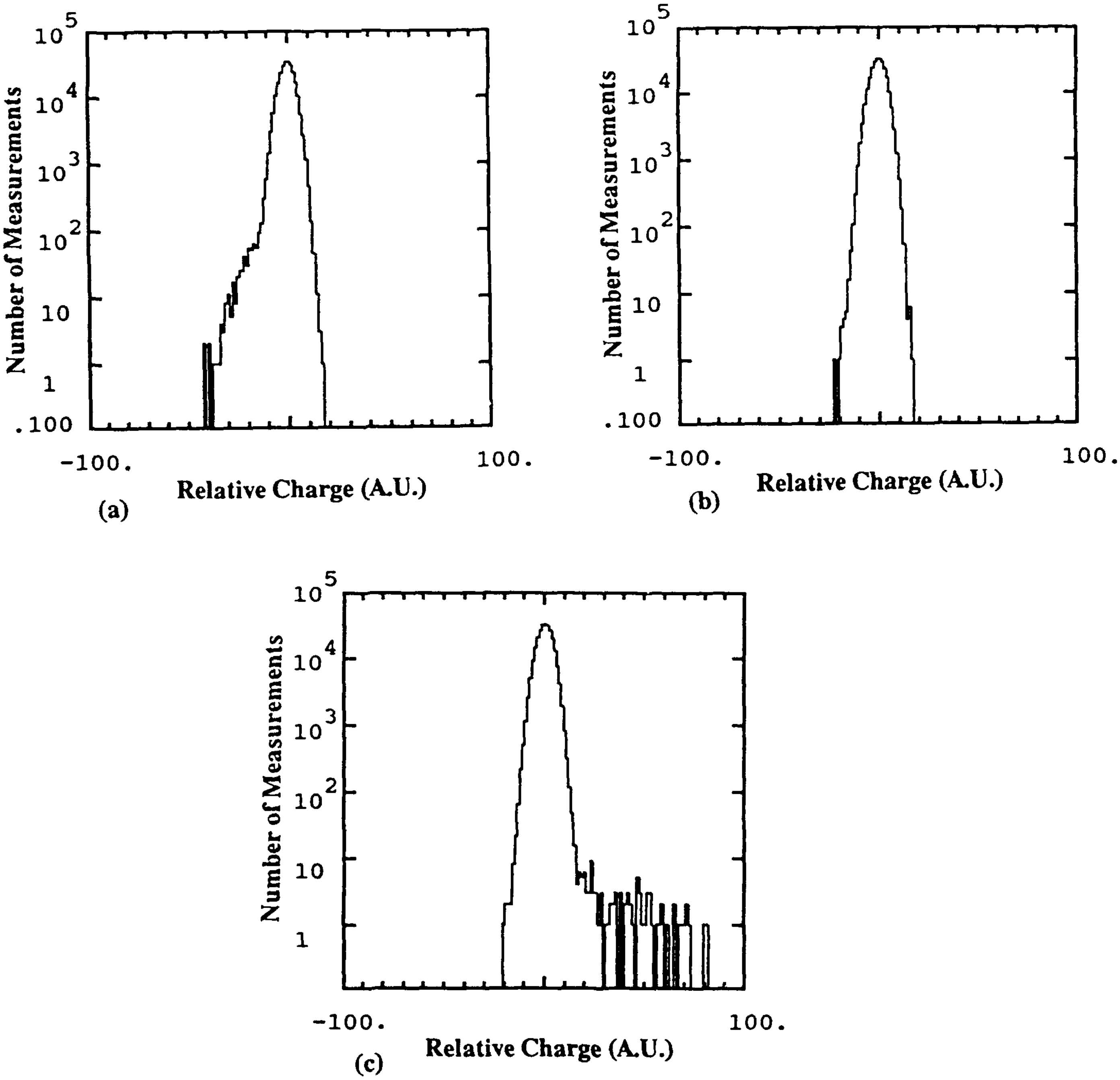

Figure 7. AMCIDERO charge readout histograms. In (a) the X-rays are applied during a 100 μs interval immediately prior to readout operation. In (b) the X-ray pulse occurs at beginning of the store period, just subsequent to the readout. In (c) the X-ray pulse is initiated just prior to the readout.

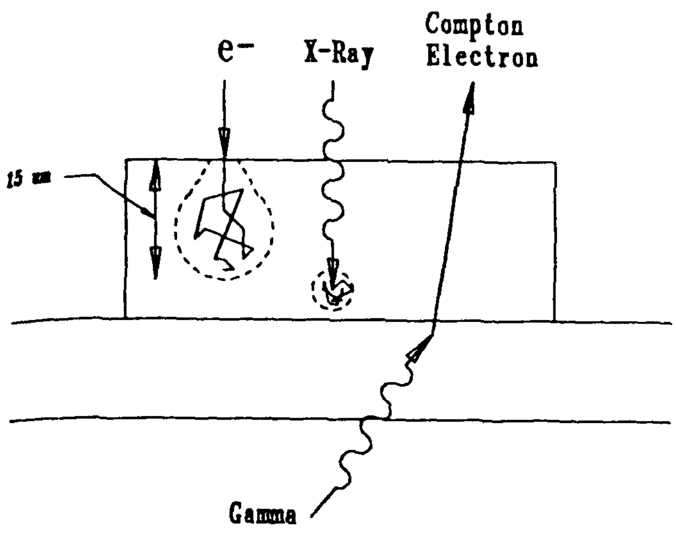

Figure 8. Comparison of ionization effects for 39 keV electrons, low energy X-rays, and gamma rays.

to get the source close to the detector, necessitating a higher intensity to compensate for divergence of the X-rays. Placing a cold shielding foil directly over the detector allows the possibility of achieving very low optical background illumination of the sample at the expense of allowing test illumination. Optimum design of test apparatus must, obviously, consider various experimental requirements and constraints.

SUMMARY

We have demonstrated how an X-ray source may be placed close to an LWIR detector, and presented an example of how the technique has been exploited. The advantages of the approach include economy of apparatus, very high potential dose rates, ease of modulation, and safety of operation.

REFERENCES

[1] L.D. Flesner, R.E. Clement, R.N. Dahle, R.L. Bates, D.C. Arrington, and W.L. Eisenman, IEEE Trans. Nucl. Sci., Vol. NS-34, No. 6, pp. 1602-1604, Dec. 1987.

[2] J.T. Montroy, R. Baron, G.C. Albright, J.C. Boisvert, and L.D. Flesner, IEEE Trans. Nucl. Sci., Vol. NS-35, No. 6, Dec., 1988.

[3] M.E. O'Brien and L.D. Flesner, "Electron Beam Testing of LWIR Detectors," Proceedings of the SPIE 1989 Technical Symposium on Aerospace Sensing, Orlando, Florida, 27-30 March, 1989, in press.

[4] For a recent reference with references to previous work, see: D.M. Fleetwood, P.S. Winokur, and J.R. Schwank, IEEE Trans. Nucl. Sci., Vol. 35, No. 6, pp. 1497-1505, Dec. 1988.